

# Sampling and Survey with AUVs in Adverse Weather Conditions

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## 1 LONG-TERM GOALS

We wish to quantify the shallow-water performance of the sensor systems and platforms in relation to harsh environmental conditions and high sea states. In particular for platforms we wish to address the performance issues with respect to navigation, communication, control and conditional mission planning during which the underwater acoustic propagation properties are severely affected by the bubble formation and mixing properties induced by storm fronts. In particular we wish to characterize the LBL sonar performance for navigation during a storm which DGPS fixes are unavailable. To accommodate a prolonged underwater survey during a passing storm, an underwater docking & power station is needed so that the AUVs can acquire power recharge and data upload if necessary. We wish to address design and implementation problems associated with our current docking design and performance in stormy conditions.

## 2 OBJECTIVES

Numerical details of mixing and acoustic properties in such adverse weather conditions remain poorly understood mainly due to the lack of experimental data for quantitative modeling and correlation analysis. During a storm passage, the induced weather condition can become so severe that surface ships are rendered inoperable for collecting during-storm measurements. One approach is to deploy beforehand a network of moored sensors. A moored system is hampered by logistical problems in deploying all sensors in a short period of time and also the deployment cost can be excessive when wide area volumetric synoptic coverage is required. It is thus of significant scientific and military interest to devise suitable underwater mobile sensing platforms which enable us to characterize the four dimensional transfer dynamics of oceanic processes synopti-

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cally. By capitalizing on the AUV technology, shallow-water oceanographic measurements in adverse weather conditions using multiple AUVs can provide a cost-effective solution in understanding the cause and effect of a storm passage. The basic idea is to provide a fixed underwater platform where an AUV can be docked with battery recharge and data upload facilities while the AUV waits for the storm. The AUV then leaves the dock during the storm to perform a volumetric survey and concludes by docking and waiting until after the storm for recovery.

The primary goal of this project is to provide suitable AUV platform support for the experiment. Specific technical goals to be addressed in this proposal are 1) to determine the limits of AUV navigation, control and communication in poor environmental conditions. High sea states in shallow water will have a large impact on the navigation and control systems of the AUV and the optimization of these systems for AUV deployment in adverse conditions can only be achieved by evaluation in progressively worsening conditions; 2) to collect synoptic and pseudo synoptic data measurements using multiple AUVs in both pre and post storm conditions; and 3) to evaluate the reliability of docking and recharge mechanisms to be used during the storm passing; 4) to identify a standard format for collecting and storing on line data, to develop software tools to handle large volumes of data collected over several missions, and to integrate the data with standard of-the-shelf commercial tools.

### 3 APPROACH

The main experiment site is chosen to be within the SFOMC range just south of Fort Lauderdale inlet, and the location will be in shallow water 5 to 50 meters deep covering an area of approximately square kilometers. This range is advantageous for this experiment because it includes a measurement range in 20m of water which allows for the *hardwiring* of sensors directly to shore. This will allow for the deployment of instrumentation before a period of adverse weather and for continuous onshore monitoring and evaluation of the data during the storm. A complementary mission site is in the Gulf of Mexico at Indian Rocks Beach near Tampa.

The dock will be a modified version of the system currently in development and testing at FAU. The dock will have a powerline feed to shore for recharging the docks batteries. The dock will have data storage for receiving uploads of AUV data and energy storage batteries to recharge the AUV. The AUV docks with a belly mounted stinger and puck assembly. Docking is performed similarly to an aircraft landing on a carrier. The dock is a bottom mounted assembly with “V” shaped slots to capture the puck on the end of the stinger. A clover leave arrangement of 4 channels allows docking from any direction. The main reason for a belly mounted approach is that the turbulence sensors must be mounted on the nose of the vehicle and are very fragile.

The puck houses a power connector and an RF antennae. An ethernet RF modem will be used to transfer data between the AUV and dock. Another RF antennae is mounted in the dock a couple of inches away from the puck when docked. Sea water experiments have shown that at this short distance RF signals will propagate between the antennas. An acoustic modem on the dock will allow the vehicle to communicate with the dock when it is nearby. Local positioning information is provided by a short base line acoustic system composed of 3 transducers mounted on a framework of aluminum pipes. This provides positioning accuracies on the order of 6” rms. The dock will be located in 60 - 70 ft. of water. This is to minimize wave disturbances while still being shallow enough for divers to reach.

To study the spatio-temporal effect of a storm front on turbulence and ambient noise fields, we

propose to carry out the experiment in three separate phases: pre-storm, during storm and post-storm surveys.

## **4 WORK COMPLETED**

A redesigned version of the "Divetracker" SBL system has been acquired and integrated into the vehicle. This system employs 3 beacons that reply on the same frequency but at different time delays. The LBL navigation software has been modified to account for the delays by incorporating AUV dead reckoning data. This navigation system has been tested at sea with AUV fly-bys and fixes the problems discovered in the original dive tracker system.

The final dock has been designed and is nearing completion. It uses a clover leaf mechanism to capture a belly mounted stinger on the AUV. This approach, although more difficult than a nose mounted approach, preserves the modular payload capability of the OEX and is compatible with the nose mounted turbulence package.

Collaborative efforts with the South Florida Ocean Measurement Center have resulted in a completed design for the offshore multiplexor and cabling to which the dock will be attached.

A two experiment at Indian Rocks Beach was completed in late February and early March of this year. This experiment included preliminary tests of AUV navigation and operational capabilities before, during, and after a storm front. The sensor systems and payloads to be used to the planned December major experiment were tested.

## **5 RESULTS**

At sea tests of the redesigned SBL system on the AUV verify that the new system provides reliable and sufficiently accurate positioning when the vehicle is moving. Tests of the AUV flight control system show that the AUV can still maintain stable flight at speeds as low as .75 m/s. This should greatly reduce the impact loading on the dock. The dock redesign is almost complete and at sea tests are scheduled for later this year.

The Indian Rocks Beach experiment provided valuable insight into the logistics of performing adverse weather operations. We were able to safely launch, operate, track, navigate, and recover the AUV in 2 meter seas in 5 meters of water. We confirmed sea state limits for stable side scan surveys (must be more than 1 wave height below the surface trough). Preliminary tests of the turbulence and ambient acoustic sensors provided needed data for improvements in preparation for the Fall Experiment.

## **6 IMPACT/APPLICATIONS**

Developing the ability to successfully operate AUV during adverse weather conditions in shallow water is expected to provide a wealth of data never before practically obtainable. Docking capability will enable the OEX and any of its modular payload sections to achieve extended mission durations. Thus enhancing both the quality and duration of the data.

## **7 RELATED PROJECTS**

Sampling and Survey with AUVs in Adverse Weather Conditions, ONR.

AUV Navigation and Platform Development, ONR.

Remote Sampling and Survey of Shallow Water Using AUVs with Application to Mine Reconnaissance, ONR.

Acoustic Communications with AUVs and Autonomous Oceanographic Sampling Network Development. ONR

ACOMS Acoustic Communication between UUV and Submarine, ONR ATD.

AUV Hydrodynamics in Shallow Water during Adverse Weather Conditions, ONR

Coordination of Experiments Using AUVs at the SFTF, ONR

ONR MURI on Nonlinear Control

USF Projects, CoBop, UK Autosub, WHOI Remus, MIT Odyssey

Advanced Machinery Control Architecture (ACMA) Laboratory Development for Automated Navy Ship Auxiliary System Control, Reconfiguration and Failure Recovery, ONR.

Dependable Network Topologies with Network Fragment Healing for Component Level Intelligent Distributed Control Systems for Naval Shipboard Automation, ONR.

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